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(54) **Digital mobile communication terminal equipment and receiving method therefor**

Mobile Endstelleneinrichtung zur Übertragung von Daten und Verfahren zu deren Empfang

Equipement mobile digital de poste terminal de communication et méthode de réception pour celui-ci

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(73) Proprietor: **NEC CORPORATION**
Tokyo (JP)

(72) Inventor: **Tsurumaru, Makoto**
Minato-ku Tokyo (JP)

(74) Representative: **Molr, Michael Christopher et al**
Mathys & Squire
100 Grays Inn Road
London WC1X 8AL (GB)

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to digital mobile communications terminal equipment and a receiving method therefor.

2. Description of Related Art

In mobile communications, it is possible to assume that its transmission line is a multiplex wave propagation path which includes a plurality of arrival routes of radio waves for a mobile station due to the influence of configuration of the land and buildings around the mobile station. In high speed transmission, wherein the difference in time between the arrival of advanced waves and delayed waves in this multiplex wave propagation is equivalent to a length of a symbol, frequency selective fading takes place, which causes an inter symbol interference between the advanced and delayed waves. An equalizer of each terminal equipment is provided for detecting a transmission signal from received data which suffer from such inter symbol interference.

An exemplary conventional receiving circuits including such an equalizer is shown in Fig. 1. Referring 1 to Fig. 1, a signal received through antenna 25 successively passes high frequency amplifier 26, intermediate frequency amplifier 27, demodulator 28 and equalizer 31 to be demodulated. Equalizer 31 includes transmission path estimating section 29 and equalizing section 30, and the output of demodulator 28 is connected to both propagation path estimating section 29 and equalizing section 30.

General operation of equalizer 31 is described subsequently. Propagating path estimating section 29 detects an auto-correlation of a known preamble bit train contained in received signal data inputted from demodulator 28 and effects estimation of a propagating path using a bit train wherein this auto-correlation function makes an impulse. A result of estimation obtained by the propagating path estimation, that is, a parameter of the amount of the inter symbol interferences, is sent to equalizing section 30, at which reverse conversion using the inter symbol interferences is performed to equalize the signal data into data which would have been transmitted from a transmitter.

The conventional receiving circuit including an equalizer is disadvantageous in that, if the communication quality is deteriorated by frequency selective fading or the like, then the received signal level drops and the error rate of demodulated data becomes high. As a countermeasure, a diversity receiving system based on comparison in received signal level is employed. However, such a diversity receiving system has a drawback in that, since the received signal level and the inter symbol interference amount have no correlation between them, even if a diversity branch of a high received signal level is selected, deterioration in characteristic caused by inter symbol interference cannot be improved. Further, diversity signal reception requires two or more receiving circuits, and consequently, there is the drawback that reduction in power consumption cannot be achieved. It is another drawback that, even if the received signal level drops to such a degree that data obtained by demodulation are in error at an error rate higher than an anticipated level and accordingly cannot be adopted as demodulated data, equalizing processing is still performed for such data, and consequently, unnecessary circuit operation is performed and excessive power consumption is wasted.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide digital mobile communications terminal equipment and a receiving method thereof wherein the error rate of data caused by residual inter symbol interference is low and power consumption is low.

In order to attain the object, according to one aspect of the present invention there is provided a digital mobile communications terminal equipment having a plurality of diversity branches and an equalizer for compensating for frequency selective fading in a received signal comprising:

a selection-after-detection diversity receiving circuit including an equalizing processing controlling circuit which starts and stops equalizing processing by said equalizer in response to a level of the received signal; and a diversity branch selecting circuit for selecting a said diversity branch on the following basis:

(i) when one only of the diversity branches has a received signal level greater than a threshold receiving level, selecting that branch;

(ii) when more than one of the diversity branches has a received signal level greater than the threshold receiving level and said more than one branches each have an intersymbol interference exceeding the equalizing capacity of the equaliser, selecting the branch with the least intersymbol interference;

(iii) when more than one of the diversity branches has a received signal level greater than the threshold receiving

level, and said more than one branches each have an intersymbol interference less than the equalising capacity of the equaliser, selecting the branch with the highest signal to noise ratio.

The number of the diversity branches may be two or three or more.

Preferably, the digital mobile communications terminal equipment comprises means for stopping operation of receiving circuits of a diversity branch which has received a signal with a level lower than the threshold receiving level.

According to another aspect of the present invention there is provided a receiving method for a digital mobile communications terminal equipment having a selection-after-detection diversity receiving circuit and an equaliser for compensating for frequency selective fading in a received signal, comprising the steps of selecting one of a plurality of diversity branches in the following basis:

(i) when one only of the diversity branches has a received signal level greater than a threshold receiving level, selecting that branch;

(ii) when more than one of the diversity branches has a received signal level greater than the threshold receiving level, and said more than one branches each have an intersymbol interference exceeding the equalising capacity of the equaliser, selecting the branch with the least intersymbol interference;

(iii) when more than one of the diversity branches has a received signal level greater than a threshold receiving level, and said more than one branches each have an intersymbol interference less than the equalising capacity of the equaliser selecting the branch with the highest signal to noise ratio.

Preferably, the receiving method for digital mobile communications terminal equipment comprises the steps of comparing the level of the received signals with a preset reference level for each diversity branch, and of stopping the receiving operation of a diversity branch which the received level is lower than a prescribed reference level.

EP-A-0.409.171 discloses a diversity receiving system which selects a diversity branch according to criteria (ii) and (iii) set forth above, but not according to criterion (i).

BRIEF DESCRIPTION OF THE DRAWINGS

The invention now will be described merely by way of example with reference to the accompanying drawings, wherein:

Fig. 1 is a block diagram of a conventional receiving circuit of digital mobile communications terminal equipment; Fig. 2 is a block diagram of a first preferred embodiment of digital mobile communications terminal equipment with a two-branch diversity receiving circuit according to the present invention;

Fig. 3 is a diagram showing the relationship between a received signal level and a data error rate;

Fig. 4 is a diagrammatic representation showing an exemplary preamble signal bit train;

Fig. 5 is a diagram showing the correlation of a preamble portion of a received wave;

Fig. 6 is a diagrammatic representation showing a received wave when a delayed wave of gain g and a 3-bit delay time is produced; and

Fig. 7 is a block diagram of a second preferred embodiment of digital mobile communication terminal equipment with three-branch diversity receiving circuit according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 2 shows a first embodiment of digital mobile communications terminal equipment with a two-branch diversity receiving circuit according to the present invention. A signal received by antenna 1-1 is successively inputted to high frequency amplifier 2-1, intermediate frequency amplifier 3-1 and demodulator 4-1, and the output of demodulator 4-1 is inputted to propagation path estimating section 5-1 and selector 9-2. The output of propagation path estimating section 5-1 is inputted to another selector 9-1. Another signal received by another antenna 1-2, which is disposed at a spatial position having no relation to the received signal of antenna 1-1, is successively inputted to high frequency amplifier 2-2, intermediate frequency amplifier 3-2 and demodulator 4-2, and the output of demodulator 4-2 is inputted to propagation path estimating section 5-2 and selector 9-2. The output of propagation path estimating section 5-2 is inputted to selector 9-1. The output of intermediate frequency amplifier 3-1 is compared as a received signal level with output level V_{ref} of reference voltage generator 8 by comparator 7-1, and the output of comparator 7-1 is connected to demodulator 4-1, propagation path estimating section 5-1, inter symbol interference amount calculating section 6-1, selectors 9-1 and 9-2, comparator 10 and equalizing section 11. Similarly, output of intermediate frequency amplifier 3-2 is compared with output level V_{ref} of reference voltage generator 8 by another comparator 7-2, and the output of comparator 7-2 is connected to demodulator 4-2, propagation path estimating section 5-2, another inter symbol inter-

ference amount calculating section 6-2, selectors 9-1 and 9-2, comparator 10 and equalizing section 11. Outputs of inter symbol interference amount calculating sections 6-1 and 6-2 are compared with each other by comparator 10, and the output of comparator 10 is inputted to selectors 9-1 and 9-2. Outputs of selectors 9-1 and 9-2 are inputted to equalizing section 11.

Fig. 3 illustrates the relationship between received signal level and data error rate, and in Fig. 3, when an anticipated data error rate is given by N, a corresponding received signal level is given by V_{ref} . Fig. 3 thus indicates that, if the received signal level is higher than V_{ref} , then such data can be treated as effective received data. Thus, level V_{ref} is set to reference voltage generator 8, and when the output of intermediate frequency amplifier 3-1 is lower than level V_{ref} , circuit operation of receiving circuit A12-1 constituted from demodulator 4-1, propagation path estimating section 5-1 and inter symbol interference amount calculating section 6-1 and of comparator 10 is stopped. Selectors 9-1 and 9-2 operate then to inhibit the output of receiving circuit A12-1. Similarly, when the output of intermediate frequency amplifier 3-2 is lower than level V_{ref} , circuit operation of another receiving circuit B12-2 constituted from demodulator 4-2, propagation path estimating section 5-2 and inter symbol interference amount calculating section 6-2 and of comparator 10 is stopped. Selectors 9-1 and 9-2 then operate to inhibit the output of receiving circuit B12-2. Equalizing section 11 stops its circuit operation when outputs of both intermediate frequency amplifiers 3-1 and 3-2 are lower than level V_{ref} . In this instance, receiving circuit A enabling signal 101 and receiving circuit B enabling signal 103 may be constantly monitored by means of a CPU (central processing unit) or the like so that error processing may be performed when both signals represent a disabling condition.

Subsequently, operation of inter symbol interference amount calculating sections 6-1 and 6-2 is described. When it is assumed that the known preamble is an M bit train signal of 26 bits (false noise) illustrated in Fig. 4 and the equalization processable time is a 4-bit sequence, the following processing is performed.

Step 0: the preamble estimation portion given by the equation (1) below is detected from a received signal:

$$R(0), R(1), \dots, R(25) \quad (1)$$

Step 1: the correlation between central 16 bits of the preamble given by equation (2) below and the received signal bit train detected at step 0, and eleven correlation values given by equation (3) below are calculated in accordance with equation (4) below:

$$C(i); i=0, 1, \dots, 15; (i) \in \{-1, +1\} \quad (2)$$

$$Corr(i); i=-5, -4, \dots, +5 \quad (3)$$

$$Corr(-5)=C(0)*R(0)+C(1)*R(1)+\dots+C(15)*R(15)$$

$$Corr(-4)=C(0)*R(1)+C(1)*R(2)+\dots+C(15)*R(16)$$

$$Corr(+5)=C(0)*R(10)+C(1)*R(11)+\dots+C(15)*R(25) \quad (4)$$

An exemplary correlation is shown in Fig. 5. Step 2: using the eleven correlation values (refer to equation (5) below) obtained at step 1, a correlation value (refer to equation (7) below) at which equation (6) presents the maximum value is calculated:

$$Corr(-5), Corr(-4), \dots, Corr(+5) \quad (5)$$

$$\{Corr(i)\}^2 + \{Corr(i+1)\}^2 + \{Corr(i+2)\}^2 + \{Corr(i+3)\}^2 + \{Corr(i+4)\}^2 \quad (6)$$

$$Corr(i)^*, Corr(i+1)^*, Corr(i+2)^*, Corr(i+3)^*, Corr(i+4)^* \quad (7)$$

The mark *** in equation (7) above represents a conjugate complex number.

Step 3: the parameter α is calculated in accordance with following equation (8):

$$\alpha = \{Corr(i)\}^2 + \{Corr(i+1)\}^2 + \{Corr(i+2)\}^2 + \{Corr(i+3)\}^2 + \{Corr(i+4)\}^2 \quad (8)$$

Step 4: another parameter β is calculated in accordance with following equation (9):

$$\beta = \sum_{i=-5}^{+5} \{\text{Corr}(i)\}^2 - \alpha \dots\dots\dots (9)$$

Step 5: the ratio between parameters α and β is calculated in accordance with the following equation to determine criterion S for the inter symbol interference amount:

$$S = \alpha/\beta$$

Selectors 9-1 and 9-2 are controlled so that criteria S1 and S2 obtained in accordance with the processing procedure as described above from inter symbol interference amount calculating sections 6-1 and 6-2, respectively, are compared with each other to select one of the branches which presents a higher value than the other. Then, equalizing processing is performed using the result of propagation path estimation of the selected branch by equalizing section 11, and equalization data 102 are outputted from equalizing section 11.

Fig. 6 illustratively shows a received wave when a delayed wave of gain g and a 3-bit delay is produced. In this instance, only inter symbol interference which is lower than the equalizing capacity of equalizing section 11 are present, and accordingly, if propagation path estimation can be performed ideally, then parameter β is reduced to "0". However, since a preamble of a limited length of 26 bits is employed in the example shown, data D(i) other than this preamble have an influence on propagation path estimation, and consequently, errors e-3 to e-5 appear in parameter β and deterioration in SN (signal-to-noise) ratio in selection of a branch takes place equivalently. Therefore, it is decided whether inter symbol interference exceeds the equivalent capacity depending upon whether the value $\alpha/(\alpha + \beta)$ exceeds fixed level "V". If the decision is such that the value exceeds fixed level "V", i.e., $\alpha/(\alpha + \beta) < V$, then parameter β includes residual inter symbol interference as a principal component, and consequently, branch selection is performed using $S = \alpha/\beta$. On the contrary, if value $\alpha/(\alpha + \beta)$ does not exceed fixed level "V", i.e., $\alpha/(\alpha + \beta) > V$, then since parameter β is dominated by such errors as described above and noise components, branch selection with a higher degree of accuracy can be made by using received preamble power $P = \alpha + \beta$ as the criterion in selection.

Referring now to Fig. 7, there is shown a second embodiment of digital mobile communications terminal equipment with a three-branch diversity receiving circuit according to the present invention. The diversity receiving circuit system of the present embodiment employs a propagation path estimating method and a branch selecting method similar to those of the diversity receiving circuit system of the preceding embodiment shown in Fig. 2, but includes three receiving circuits so that the advantage of a system having higher receiving characteristics than that of the first embodiment is achieved.

Claims

1. Digital mobile communications terminal equipment having a plurality of diversity branches (12-1,12-2) and an equalizer (11) for compensating for frequency selective fading in a received signal comprising:
 - a selection-after-detection diversity receiving circuit including an equalizing processing controlling circuit which starts and stops equalizing processing by said equalizer in response to a level of the received signal; and a diversity branch selecting circuit (7-1,7-2,9-1,9-2,10) for selecting a said diversity branch on the following basis:
 - (i) when one only of the diversity branches has a received signal level greater than a threshold receiving level, selecting that branch;
 - (ii) when more than one of the diversity branches has a received signal level greater than the threshold receiving level and said more than one branches each have an intersymbol interference exceeding the equalizing capacity of the equaliser, selecting the branch with the least intersymbol interference;
 - (iii) when more than one of the diversity branches has a received signal level greater than the threshold receiving level, and said more than one branches each have an intersymbol interference less than the equalising capacity of the equaliser, selecting the branch with the highest signal to noise ratio.
2. Digital mobile communications terminal equipment as claimed in Claim 1, wherein the number of diversity branches is two.
3. Digital mobile communications terminal equipment as claimed in Claim 1, wherein the number of the diversity branches is three or more.

4. Digital mobile communications terminal equipment as claimed in any one of Claims 1 to 3, comprising means (7-1,7-2) for stopping operation of a receiving circuit of a diversity branch which has a received signal level lower than the threshold receiving level.

5. A receiving method for digital mobile communications terminal equipment having a selection-after-detection diversity receiving circuit and an equaliser for compensating for frequency selective fading in a received signal, comprising the steps of selecting one of a plurality of diversity branches in the following basis:

(i) when one only of the diversity branches has a received signal level greater than a threshold receiving level, selecting that branch;

(ii) when more than one of the diversity branches has a received signal level greater than the threshold receiving level, and said more than one branches each have an intersymbol interference exceeding the equalising capacity of the equaliser, selecting the branch with the least intersymbol interference;

(iii) when more than one of the diversity branches has a received signal level greater than the threshold receiving level, and said more than one branches each have an intersymbol interference less than the equalising capacity of the equaliser selecting the branch with the highest signal to noise ratio.

6. A receiving method for digital mobile communications terminal equipment as claim in Claim 5, comprising stopping the receiving operation of each diversity branch whose received signal level is lower than the threshold receiving level.

Patentansprüche

1. Digitale mobile Datenübertragungsstations-Einrichtung mit einer Vielzahl von Diversity- oder Mehrfachempfangszweigen (12-1,12-2) und mit einer Entzerrerschaltung (11) zum Kompensieren von frequenzselektivem Schwund in einem empfangenen Signal, die aufweist:

eine Auswahl-Nach-Detektion-Diversity-Empfangsschaltung, die eine entzerrende Verarbeitungssteuerschaltung einschließt, die die entzerrende Verarbeitung durch die Entzerrerschaltung als Reaktion auf den Pegel eines empfangenen Signals beginnt und beendet; und
eine Diversity-Zweigauswahlschaltung (7-1,7-2,9-1,9-2,10) zum Auswählen des Diversity-Zweiges basierend auf folgendem:

(i) wenn nur einer der Diversity-Zweige einen Pegel des empfangenen Signals aufweist, der größer ist als ein Schwellenempfangspegel, diesen Zweig auszuwählen;

(ii) wenn mehr als einer der Diversity-Zweige einen Pegel des empfangenen Signals aufweist, der größer ist als der Schwellenempfangspegel, und wenn jeder dieser mehr als einen Zweige eine gegenseitige Zeichenbeeinflussung aufweist, die die Entzerrungsfähigkeit der Entzerrerschaltung überschreitet, den Zweig auszuwählen, der die geringste gegenseitige Beeinflussung hat;

(iii) wenn mehr als einer der Diversity-Zweige einen Pegel des empfangenen Signals aufweist, der größer ist als der Schwellenempfangspegel, und wenn jeder der mehr als einen Zweige eine gegenseitige Zeichenbeeinflussung hat, die geringer ist als die Entzerrungskapazität der Entzerrerschaltung, den Zweig mit dem höchsten Signal-Zu-Rauschen-Verhältnis auszuwählen.

2. Digitale mobile Datenübertragungsstations-Einrichtung nach Anspruch 1, bei der die Anzahl der Diversity-Zweige zwei ist.

3. Digitale mobile Datenübertragungsstations-Einrichtung nach Anspruch 1, bei der die Anzahl der Diversity-Zweige drei oder mehr ist.

4. Digitale mobile Datenübertragungsstations-Einrichtung nach einem der Ansprüche 1 bis 3, die Mittel (7-1,7-2) zum Beenden des Betriebs einer Empfangsschaltung eines Diversity-Zweiges aufweist, der einen Pegel des empfangenen Signals hat, der kleiner ist als der Schwellenempfangspegel.

5. Empfangsverfahren für digitale mobile Datenübertragungsstations-Einrichtungen, die eine Auswahl-Nach-Detek-

tion-Diversity- oder Mehrfachempfangsschaltung und eine Entzerrerschaltung zum Kompensieren für frequenzselektiven Schwund in einem empfangenen Signal besitzt, das die Schritte aufweist, einen einer Vielzahl von Diversity-Zweige basierend auf dem folgenden auszuwählen:

(i) wenn nur einer der Diversity-Zweige einen Pegel des empfangenen Signals aufweist, der größer ist als ein Schwellenempfangspegel, diesen Zweig auszuwählen;

(ii) wenn mehr als einer der Diversity-Zweige einen Pegel des empfangenen Signals aufweist, der größer ist als der Schwellenempfangspegel, und wenn jeder dieser mehr als einen Zweige eine gegenseitige Zeichenbeeinflussung aufweist, die die Entzerrungsfähigkeit der Entzerrerschaltung überschreitet, den Zweig auszuwählen, der die geringste gegenseitige Zeichenbeeinflussung hat;

(iii) wenn mehr als einer der Diversity-Zweige einen Pegel des empfangenen Signals aufweist, der größer ist als der Schwellenempfangspegel, und wenn jeder der mehr als einen Zweige eine gegenseitige Zeichenbeeinflussung hat, die geringer ist als die Entzerrungskapazität der Entzerrerschaltung, den Zweig mit dem höchsten Signal-Zu-Rauschen-Verhältnis auszuwählen.

6. Empfangsverfahren für digitale mobile Datenübertragungsstations-Einrichtungen nach Anspruch 5, das es aufweist, den Empfangsbetrieb jedes Diversity-Zweiges zu beenden, dessen Pegel des empfangenen Signals niedriger ist als der Schwellenempfangspegel.

Revendications

1. Equipement de terminal de communications mobile numérique possédant une pluralité de branches de diversité (12-1, 12-2) et un égaliseur (11) pour compenser l'affaiblissement sélectif en fréquence dans un signal reçu, comportant :

un circuit récepteur de diversité à sélection-après-détection contenant un circuit de commande de traitement d'égalisation qui fait démarrer et arrête le traitement d'égalisation par ledit égaliseur en réponse à un niveau du signal reçu; et

un circuit de sélection de branche de diversité (7-1, 7-2, 9-1, 9-2, 10) destiné à sélectionner une dite branche de diversité sur la base suivante :

(i) lorsqu'une seule des branches de diversité a un niveau de signal reçu supérieur à un seuil de niveau de réception, sélectionner cette branche;

(ii) lorsque plus d'une des branches de diversité a un niveau de signal reçu supérieur au seuil de niveau de réception et que chacune de ces branches a une interférence intersymboles excédant la capacité d'égalisation de l'égaliseur, sélectionner la branche qui présente l'interférence intersymboles la plus faible;

(iii) lorsque plus d'une des branches de diversité a un niveau de signal reçu supérieur au seuil de niveau de réception et que chacune de ces branches a une interférence intersymboles inférieure à la capacité d'égalisation de l'égaliseur, sélectionner la branche qui présente le rapport signal/bruit le plus élevé.

2. Equipement de terminal de communications mobile numérique selon la revendication 1, dans lequel le nombre de branches de diversité est de deux.

3. Equipement de terminal de communications mobile numérique selon la revendication 1, dans lequel le nombre de branches de diversité est de trois ou plus.

4. Equipement de terminal de communications mobile numérique selon l'une quelconque des revendications 1 à 3, comprenant des moyens (7-1, 7-2) destinés à arrêter le fonctionnement d'un circuit de réception d'une branche de diversité qui a un niveau de signal reçu inférieur au seuil de niveau de réception.

5. Procédé de réception pour équipement de terminal de communications mobile numérique possédant un circuit récepteur de diversité à sélection-après-détection et un égaliseur pour compenser l'affaiblissement sélectif en fréquence dans un signal reçu, comportant les étapes de sélection d'une parmi une pluralité de branches de diversité sur la base suivante :

(i) lorsqu'une seule des branches de diversité a un niveau de signal reçu supérieur à un seuil de niveau de

réception, sélectionner cette branche;

(ii) lorsque plus d'une des branches de diversité a un niveau de signal reçu supérieur au seuil de niveau de réception et que chacune de ces branches a une interférence intersymboles excédant la capacité d'égalisation de l'égaliseur, sélectionner la branche qui présente l'interférence intersymboles la plus faible;

(iii) lorsque plus d'une des branches de diversité a un niveau de signal reçu supérieur au seuil de niveau de réception et que chacune de ces branches a une interférence intersymboles inférieure à la capacité d'égalisation de l'égaliseur, sélectionner la branche qui présente le rapport signal/bruit le plus élevé.

6. Procédé de réception pour équipement de terminal de communications mobile numérique selon la revendication 5, comportant l'arrêt de l'opération de réception de chaque branche de diversité dont le niveau de signal reçu est inférieur au seuil de niveau de réception.

FIG.1
(PRIOR ART)

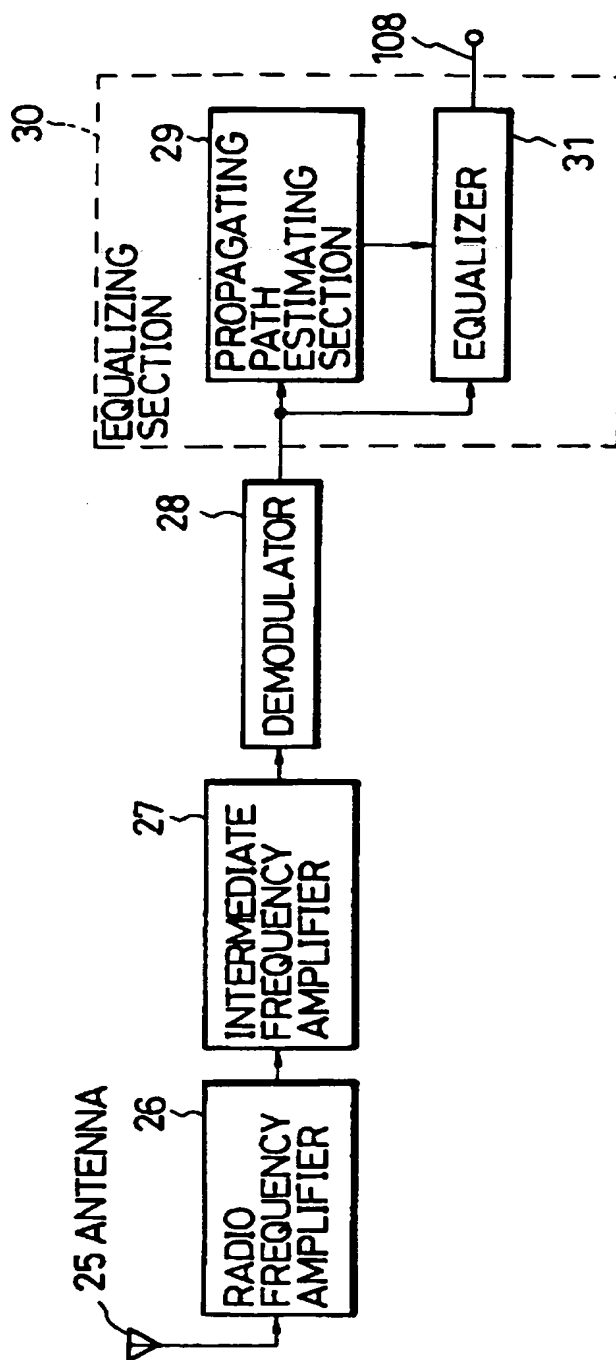


FIG. 2

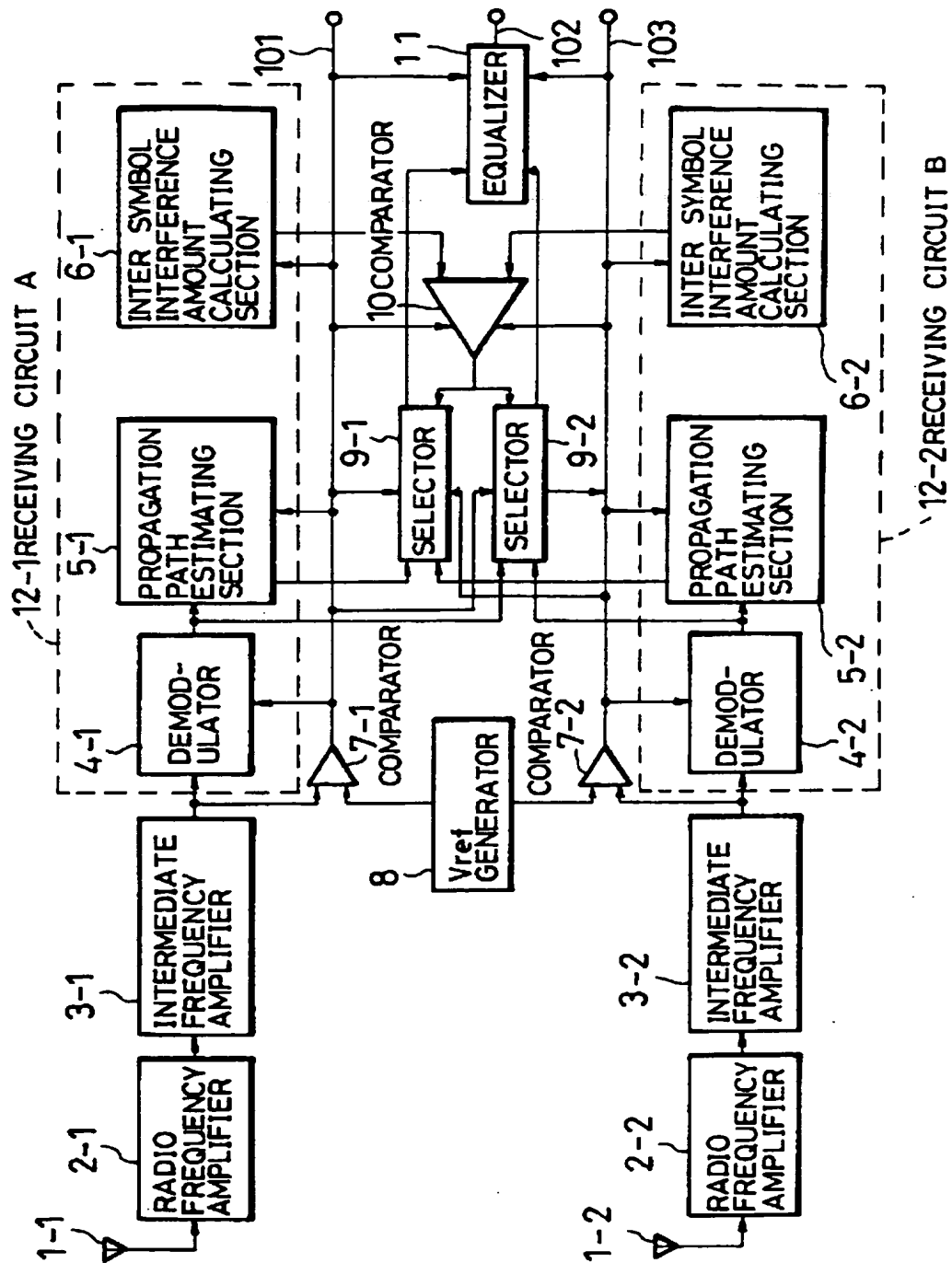


FIG. 3

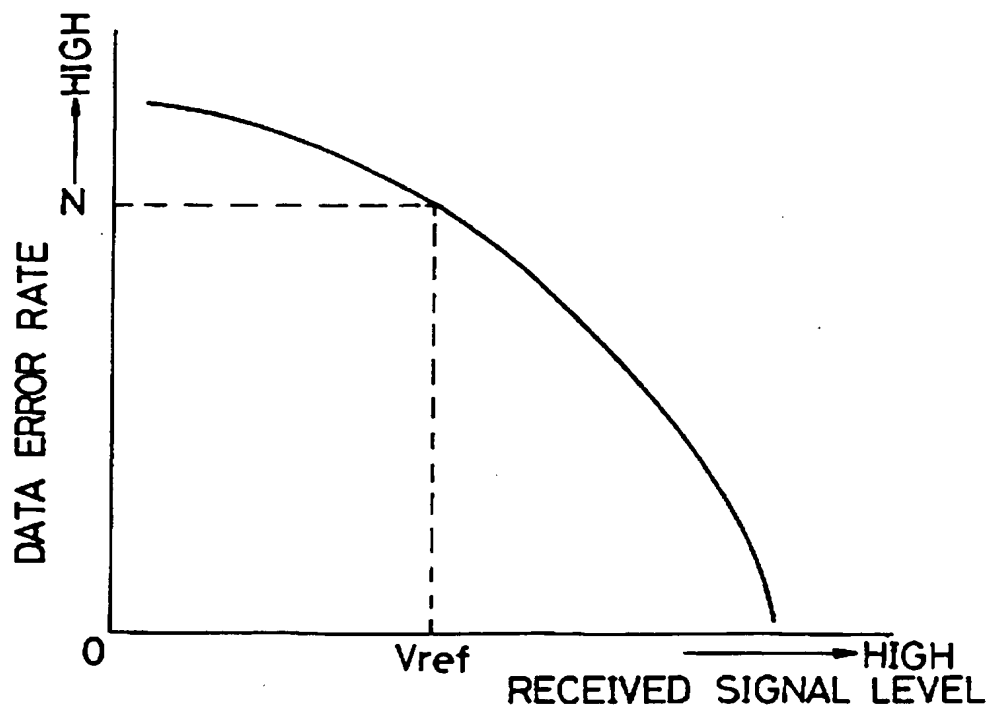


FIG. 4

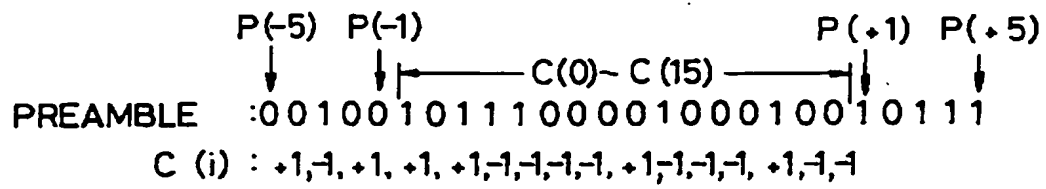


FIG. 5

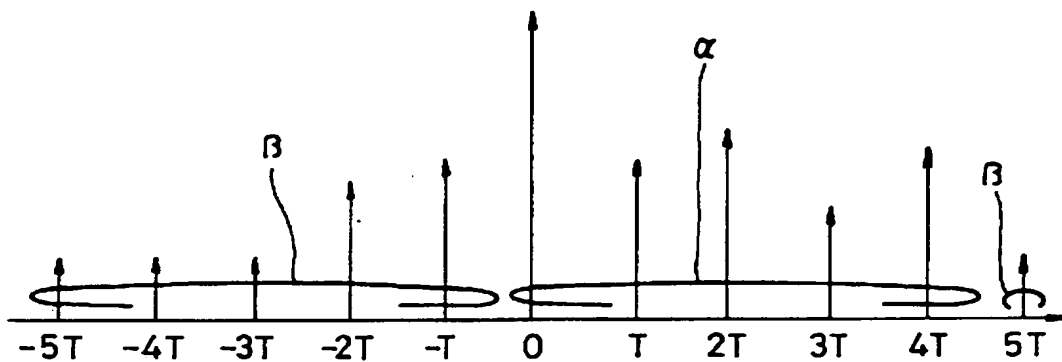


FIG. 6

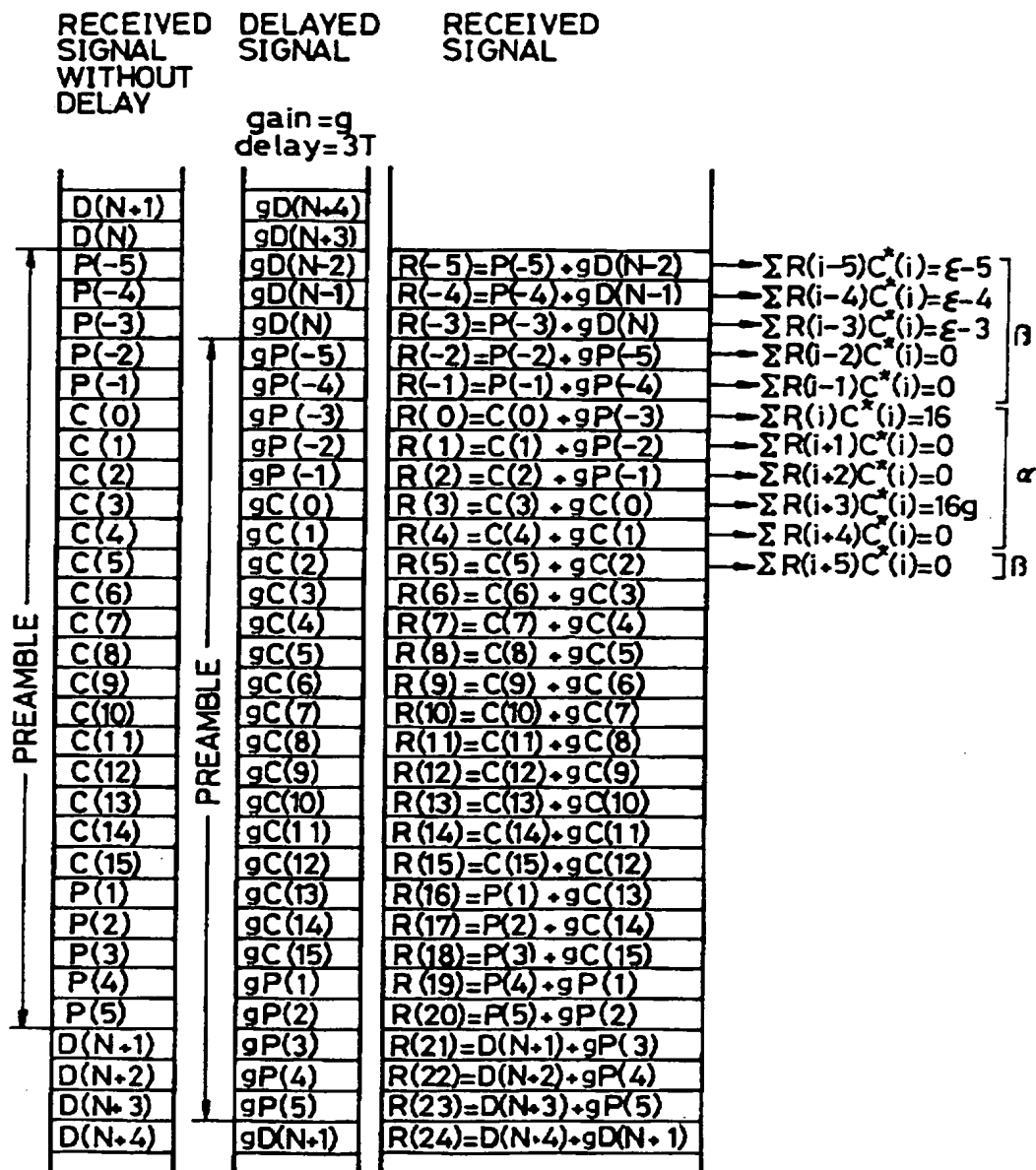


FIG. 7

